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# Variation in agronomic characters among high and low nitrogen $S_2$ maize (*Zea mays* L) lines grown in high and low nitrogen environments

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## Abstract

Poor soil fertility, especially with low levels nitrogen (N), is a major constraint to productivity and the production of maize in Sub-Saharan Africa (SSA). This phenomenon has raised the need to combine the breeding goals of yield improvement for conditions with low levels of N and yield improvement for conditions with high input of N fertilizer. The objective of this study was to evaluate variation in agronomic characters, heritability, genotype x environment (GxE), and predicted gains from selection of high and low N $S_2$ maize breeding lines in both high and low N environments. Fertilizer was not applied in low N environments, while the high N environments were fertilized at the rate of 150 kg N, 75 kg $P_2O_5$ and 75 kg $K_2O$ per hectare. The high and low N $S_2$ progenies were evaluated under high and low N environments respectively in the research farms of the Nigerian Institute for Oil Palm Research (NIFOR), near Benin City (Latitude 6o 33' N and Longitude 5°33'E), Edo State and Delta State College of Agriculture, Ozoro (latitude 6°13'E and longitude 5°33'N). Both locations are situated in the rainforest ecological zone of Nigeria with average rainfall of 2,500 mm. The experimental designs used for both high and low N environments were 10 x 10 and 8 x 8 lattices respectively. The mean squares for the two high N environments were significant for all agronomic traits evaluated. Moreover, the mean squares for the high N $S_2$ progenies were significant for all the observed agronomic characters except ear height and leaf senescence. The high N progenies x environments interaction was significant in most of the observed agronomic characters except leaf area, ear height and leaf senescence. On the contrary, the mean squares for the two low N environments were significant for all the observed agronomic characters except leaf senescence. Significant mean squares were observed among low N $S_2$ progenies in leaf area, ear height, leaf senescence and grain yield. However, there was no low N x environment interaction for all the observed agronomic characters. Grain yield of low N $S_2$ progenies was only 5.46% of the yield obtained among high N $S_2$ progenies. Nitrogen stress resulted in reduction of growth (height) and yield of low N $S_2$ progenies by 52.3% and 94.5%, respectively. Low N environments resulted in lower broadsense heritability than high N in most of the observed agronomic characters except plant height, leaf senescence and ear height. Heritability estimates in low N and high N ranged from -9.8 to 53.9% and -7.8 to 59.5%, respectively. The results indicated that the magnitude of genetic variance, heritability, and gains from selection are dependent on the nature of the crop environment. In spite of lower heritability under low N stress conditions, selection under low N would be more efficient than selection under high N for targeting low N stress environment.

**Keywords**: maize, variation, high N, low N, $S_2$ lines, heritability

## Introduction

It is commonly observed that most soils found in humid regions of the world, especially those in subtropical areas where a greater proportion of the population live, are nutrient poor. Population pressure has resulted in a reduction in the length of fallow periods, leading to a decline in soil fertility. The production of high- value crops on more favoured land has resulted in maize production moving to more marginal areas. These changes imply that soils with low nutrient availability, especially nitrogen will more commonly be used for maize production in the future (Banziger and Lafitte, 1997; Meseka et al, 2006). This phenomenon has raised the need to combine the breeding goals of yield improvement for conditions with low levels of N and yield improvement for conditions with high input of N fertilizer.

Efforts to improve maize adaptation to low soil fertility have been documented in literature (Muruli and Paulsen, 1981; Lafitte and Edmeades, 1994b; Banziger and Lafitte, 1997; Banziger et al, 1997; Santos et al, 1998; Meseka et al, 2006). Maize is highly sensitive to soils deficient in plant nutrients especially nitrogen, requiring large additions of fertilizer to produce high yields while increasing production cost. Because breeding is mostly conducted in the presence of high inputs, it has systematically missed the opportunity to exploit genetic differences at low levels of inputs. Many studies show that these differences do exist, particularly in the case of fertilizers, and that these differences can only be identified if selection is conducted under the target level of inputs (Muruli and Paulsen, 1981; Ceccarelli, 1996; Banziger



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and Lafitte, 1997; Banziger et al, 1997). Although this was predicted by theory more than 40 years ago (Falconer, 1952), and has been supported by large body of experimental data, very few breeders select in suboptimal or stress conditions (Rosielle and Hamblin, 1981; Simmonds, 1991; Falconer, 1993; Ceccarelli, 1996). The most common justification is the high environmental variation, and hence the lower heritability expected in low input conditions. While this is not supported by experimental evidence, it has been shown by Ceccarelli (1996) that in the case of a typical crop grown in low-input and climatically marginal conditions such as barley, genetic gains are possible by using locally adapted germplasm and by selecting in target environment.

At CIMMYT, simultaneous selection in a lowland tropical maize population under low and high N led to similar selection gains under low N and high N (Lafitte and Edmeades, 1994b). However, the relative contribution of each selection environment to selection gains was not assessed. Another study at CIMMYT by Banziger et al (1997) showed that direct selection was likely to be more efficient than indirect selection for improving grain yields under low-N target environments. In another study, Banziger and Lafitte (1997) evaluated the relative value of anthesis- silking interval (AS1), number of ears per plant, leaf chlorophyll concentration and leaf senescence for improving the identification of high yielding maize genotypes in low–N selection environments. They concluded that secondary traits are valuable adjuncts in increasing the efficiency of selection for grain yield when broad-sense heritability for grain yield is low (i.e under low-N). The study conducted by Santos et al, (1998) to characterize and evaluate maize germplasm in low-fertility soil with severe phosphorus limitations also indicated that selection in good environments may not be efficient in improving performance in low-fertility environments. It was concluded that the wide range of variation exhibited by the accessions indicates that it is possible to select and utilize genetic resources in less-developed regions in order to maintain sustainable agriculture. Meseka et al (2006) also highlighted the importance of screening drought tolerant maize inbred lines under low N to enhance opportunities for identifying parents of single-cross hybrids for low N environments. So far, a majority of previous studies were conducted using European and US source materials and further studies were, therefore, needed to evaluate genotypic variation for grain yield and other traits in high and low N environments using tropical maize $S_2$ progenies. This present study evaluated variation in agronomic characters, heritability, genotype x environment (GxE), as well as predicted gains from selection of high and low N $S_2$ maize breeding lines in both high and low N environments.

## Materials and Methods

The Second generation selfed ($S_2$) maize lines used in this study were developed from an open pollinated (OP) elite cultivar; TZBR ELD.3C2 with considerable genetic diversity. Selfing was carried out in the breeding nursery of the Department of Crop Science, University of Benin, Benin City in two environments i.e., high N and low N respectively. A total of 100 $S_2$ high N and 64 $S_2$ low N progenies were developed under high N and low N environments respectively. Fertilizer was not applied in low N environments, while the high N environment was fertilized at the rate of 150 kg N, 75 kg $P_2O_5$ and 75 kg $K_2O$ per hectare. The evaluation of both high and low N $S_2$ progenies was carried out in the research farms of the Nigerian Institute for Oil Palm Research (NIFOR), near Benin City (Latitude 6°33'N, Longitude 5°33'E), Edo State, and Delta State College of Agriculture, Ozoro (latitude 6°13'E, longitude: 5°33'N). Both locations are situated in the rainforest ecological zone of Nigeria with average rainfall of 2,500 mm. The 100 $S_2$ high N progenies were evaluated under high N, while the 64 $S_2$ low N progenies were evaluated under low N in each location. The low N environments were not fertilized, while the high N environments received 150 kg N, 75 kg $P_2O_5$ and 75 kg $K_2O$ per ha. The experimental design was a 10 x 10 lattice design for high N environments, while an 8 x 8 lattice was used for low N environments with three replications (Cochran and Cox, 1957). However, data were analyzed as randomized complete block design rather than as lattice design. Each $S_2$ progeny was planted in single row plots 3 m long with 75 cm between rows and 50 cm

Table 1 - Soil Physical and Chemical Properties of the experimental sites for 100 high-N $S_2$ and 64 low-N $S_2$ maize progenies grown in high - N and low - N environments respectively at NIFOR, Near Benin City and Ozoro, Delta State.

| Sample | Mechanical Analysis | | | | pH (1 : 1) | Exchange | Organic | Total | Available | Exchangeable Cations (meq./100g) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sand | Silt | Clay | Textural | $H_2O$ | Acidity (EA) | Carbon | N | P | Ca | Mg | Na | K | ECEC |
| | % | % | % | class | | Cmol $Kg^{-1}$ | % | % | (ppm) | | | | | Cmol $Kg^{-1}$ |
| NIFOR high - N (BP) | 84.00 | 2.00 | 14.00 | Sandy Loamy | 5.89 | 0.31 | 0.64 | 0.07 | 1.43 | 1.41 | 0.85 | 0.07 | 0.19 | 2.83 |
| NIFOR high - N (AH) | 84.00 | 1.00 | 15.00 | Sandy Loamy | 5.45 | 1.04 | 0.62 | 0.03 | 1.00 | 0.96 | 0.58 | 0.04 | 0.17 | 2.79 |
| NIFOR low - N (BP) | 84.00 | 1.00 | 15.00 | Sandy Loamy | 5.73 | 0.78 | 0.78 | 0.07 | 1.49 | 1.29 | 0.78 | 0.07 | 0.08 | 3.00 |
| NIFOR low - N (AH) | 83.00 | 2.00 | 15.00 | Sandy Loamy | 6.29 | 0.19 | 1.08 | 0.05 | 7.30 | 1.12 | 0.68 | 0.05 | 0.08 | 2.12 |
| Ozoro high - N (BP) | 84.00 | 2.00 | 14.00 | Sandy Loamy | 5.32 | 1.16 | 1.01 | 0.08 | 5.31 | 0.48 | 0.29 | 0.10 | 0.18 | 2.21 |
| Ozoro high - N (AH) | 83.00 | 3.00 | 14.00 | Sandy Loamy | 5.06 | 2.07 | 0.85 | 0.11 | 4.31 | 0.49 | 0.30 | 0.14 | 0.13 | 3.13 |
| Ozoro low - N (BP) | 84.00 | 2.00 | 14.00 | Sandy Loamy | 4.54 | 2.64 | 0.77 | 0.07 | 2.84 | 0.36 | 0.22 | 0.12 | 0.17 | 3.51 |
| Ozoro low - N (AH) | 83.00 | 3.00 | 14.00 | Sandy Loamy | 5.24 | 1.52 | 0.85 | 0.04 | 4.31 | 0.46 | 0.28 | 0.14 | 0.10 | 2.50 |

BP = Before Planting , AH = After Harvest

within rows at two plants per stand (53,333 plants per hectare). They were over sown and thinned to the desired plant density, and they were kept free of weeds. The high and low N experiments were planted in the same cropping season at NIFOR and Ozoro. Low and high N fields were adjacent to each other and except for N, P and K fertilization; management was same for both N levels.

Prior to sowing in each evaluation site and at harvest, soil samples were collected at random from a depth of 0-30 cm for physical and chemical analysis.

Days from sowing to 50% pollen shed (anthesis date) and 50% silk extrusion (silking date) were determined using all plants in a plot and ASI was calculated as (silking date - anthesis). Leaf area of two plants per plot was measured two weeks after the silking stage. Area of individual blades was calculated as LxWx0.75 (Hassan et al, 2010), where L and W are maximum blade length and width respectively. Plant height was taken at maturity from ground level to collar of the most upper leaf of the plant. Ear height was also taken at maturity from ground level to upper most ears. Leaf senescence was determined either by counting the number of green leaves remaining below the upper ear on six plants at approximately three and five weeks after anthesis, or by visually estimating the percentage of leaf area remaining in each plot on two to three occasions during grain filling.

Ears were harvested from a bordered area at physiological maturity, ear number was determined, and ears per plant calculated. Ears were weighed on the field and seed samples were collected for each maize line for determination of moisture content percentage at harvest. Ears were dried, shelled and shelling percentage was determined for each maize line. Grain yield, expressed in t ha$^{-1}$, was obtained by multiplying the field weight with the shelling percentage and was adjusted to 15% moisture.

Soil samples were analyzed prior to experimentation and after harvest of crops. Soil pH was determined using a pH meter in a 1:1 soil/water suspension. Total nitrogen was determined by the Kjeldahl method (Udo et al, 2009), available phosphorus by the method of Bray and Kurtz (1945), available cations by flame photometry, and manganese and iron by atomic spectrophotometry (Perkin-Elmer Model 403). Organic carbon was measured by the wet combustion method of Walkley and Black (1934).

***Statistical Analysis***

Analysis of variance was calculated for each trial separately with SAS Software Computer Package (SAS, 2002). All factors were considered as random effects. Genotypic variances ($\sigma_G^2$), genotypic by environment interaction ($\sigma_{GE}^2$) and error variances ($\sigma_E^2$) were estimated from the ANOVA table calculated for each experiment as follows (Snedecor and Cochran, 1980):

$\sigma_G^2 = (MS\ S^2\ progenies - MS_{GE}) / re$

$\sigma_{GE}^2 = (MS_{GE} - MS_E) / r$

$\sigma_E^2 = MS_{error}$,

where MS $S_2$ progenies, $MS_{GE}$ and $MS_{error}$ are mean squares for $S_2$ progenies, genotype x environment interactions and error, respectively from the ANOVA table, while r is number of replications, and e is the number of environments.

Broad-sense heritabilities ($h^2$) were calculated on an entry mean basis as Fountain and Hallauer (1996)

$h^2 = \sigma_G^2 / (\sigma_E^2/re + \sigma_{GE}^2/e + \sigma_G^2)$,

where r is the number of replications and e is the number of environments. Variance components such as genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) were assessed according to the methods of Singh and Chaudhaury (1977) as follows:

$$GCV = \sqrt{s_G^2}/\bar{x} \cdot 100 / 1,$$

where $\sigma_G^2$ is the genotypic variance and $\bar{x}$ is the population mean of the $S_2$ progenies.

$$PCV = \sqrt{s_P^2}/\bar{x} \cdot 100 / 1,$$

where $\sigma_P^2$ is the phenotypic variance and $\bar{x}$ is the population mean of the $S_2$ progenies.

Predicted genetic gain from selection ($G_s$) was calculated using the formular adapted from Falconer

Table 2 - Analysis of Variance for agronomic traits among 100 S2 maize progenies in two high nitrogen environments at NIFOR, near Benin City and Ozoro, Deita State.

| Source of Variation | DF | Mean Square | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 50% tasseling | 50% pollen | 50% silking | ASI | Leaf Area (cm$^2$) | Plant Height (cm) | Ear Height (cm) | Leaf Senescence | Grain Yield (t ha$^{-1}$) |
| Location | 1 | 3864.9** | 3264.7** | 4681.1** | 124.4** | 3124760** | 502667.8** | 264883.8** | 6618.7* | 715331872** |
| Rep (Location) | 4 | 94.1 | 107.7 | 656.2 | 6.5 | 78874.3** | 3094.4* | 6181.7 | 1055.7 | 4115727.8** |
| Block(Location*Replication) | 54 | 87.5 | 95.3 | 104.7 | 7** | 29439** | 3069.7** | 5865.7 | 1402.8 | 4995134.8** |
| Progeny | 99 | 112.7** | 129** | 139.4** | 7.9** | 22905.5** | 2727.9** | 4693.1 | 1261.2 | 3678636.9** |
| Location*Progeny | 99 | 105.8** | 110.6* | 123.9** | 6.2** | 9729.9 | 2378.1** | 5057.1 | 1320.0 | 1490836.1** |
| Error | 321 | 66.2 | 73.7 | 79.1 | 4.0 | 7772.4 | 1254.5 | 5216.6 | 1429.9 | 985542 |
| Total | 578 | | | | | | | | | |

*, ** Significant at 0.05 and 0.01 probability levels, respectively

(1981) as Gs = $k\sigma_G h$, while response to selection expressed as percentage of mean (Emede and Alika, 2005) was calculated as:

Rs = $k\sigma_G h$ 100 / $\bar{x}$,

where $\sigma_G$ is the square root of the genotypic variance among the $S_2$ progenies, h is the square root of the estimate of heritability on progeny mean basis, $\bar{x}$ is the population mean, and k is the standardized selection differential. Since 20% of the population was saved as $S_2$ progenies from both high and low N environments, k = 1.4.

## Results

The soil physical and chemical properties of the experimental sites before planting (BP) and after harvest (AH) are presented in Table 1. The textural class of the Soils of NIFOR and Ozoro, before planting (BP) and after harvest (AH) was sandy Loam. The soil pH ranged from 5.45 – 6.29 in both low and high N environments in NIFOR, while it ranged from 4.54 to 5.32 in Ozoro (Table 5). The exchanged acidity was correspondingly higher in OZORO experimental sites than NIFOR. However, in both NIFOR and Ozoro soil acidity and exchange acidity increased in high N environments, while there was a decrease in both soil acidity and exchange acidity in low N environments. Organic carbon was 0.64% and 1.01% in NIFOR high N and Ozoro high N environments respectively at planting. The organic carbon was reduced after harvest in both NIFOR and Ozoro high N environments. However, this was the reverse in both NIFOR and Ozoro low N environments (Table 1).

Significant difference was observed between the two high N environments for all the agronomic characteristics evaluated. Moreover, there was significant difference among the 100 high N $S_2$ progenies for all the observed agronomic characters except ear height and leaf senescence. Also, there was significant high N progeny-by-environment interaction for most characters except leaf area, ear height and leaf senescence (Table 4). The mean grain yield across the two high nitrogen environments was 2.25 t $ha^{-1}$ (Table 9).

In low nitrogen N, there was significant difference between the two locations (NIFOR and Ozoro ) for all observed agronomic characters except leaf senescence. The 64 low N $S_2$ progenies differed significantly only in leaf area, ear height; leaf senescence and grain yield (Table 3). However, there was no low N progeny by environment interaction for all the observed agronomic characters. Low N $S_2$ progenies across the two low N environments were earlier in days to 50% pollen shedding, silking, and tasseling than high nitrogen. The mean grain yield across the two low nitrogen environments was 0.12 t $ha^{-1}$ (Table 5). Grain yield of low N $S_2$ progenies under low N was only 5.46% of the yield obtained among high N $S_2$ progenies under high N. Also, the mean values for leaf area, plant height, leaf senescence, and ear height among low N progenies were lesser than high N.

Among flowering characters, error variance ($\sigma_E^2$) was fairly greater under low N than under high N. However, for morphological characters and grain yield error variance was far greater under higher N than low N. Although there was no significant genotype-by-environment interaction for all agronomic characteristics under low nitrogen, the estimates for genotype-by-environment variance ($\sigma_{GE}^2$) for flowering characters under low N was almost of the same magnitude under high N (Tables 4 and 5). However, estimates of $\sigma_{GE}^2$ for morphological characteristics among the 64 low N progenies under low N were fairly lower and even zero for grain yield. On the contrary, estimates of $\sigma_{GE}^2$ for morphological characteristics and grain yield among the 100 high N progenies under high N environment were greater except for leaf senescence and ear height that had negative $\sigma_{GE}^2$ estimates.

Estimates of genetic component of variance ($\sigma_G^2$) for flowering characteristics among the 64 low N progenies under low N were greater than high N except for days to 50% silking and ASI. On the con-

Table 3 - Analysis of Variance (ANOVA) for Agronomic Traits among 64 $S_2$ maize progenies in two low Nitrogen environments at NIFOR, near Benin City and Ozoro, Deita State.

| Source of Variation | DF | Mean Square | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 50% tasseling | 50% pollen | 50% silking | ASI | Leaf Area ($cm^2$) | Plant Height (cm) | Ear Height (cm) | Leaf Senescence | Grain Yield (t $ha^{-1}$) |
| Location | 1 | 4340.3** | 3793.9** | 6558.8** | 376** | 33832.4** | 6582.5** | 42201.7** | 1.4 | 34.4** |
| Rep (Location) | 4 | 189.3 | 77.4 | 80.3 | 3.3 | 12335.1** | 710.7 | 1439.3** | 12.4** | 3.8 |
| Block(Location*Replication) | 42 | 641.9** | 950.7** | 1052.2** | 14.3** | 25746.8** | 2777.2** | 1218.2** | 8.5** | 5.2** |
| Progeny | 63 | 321.5 | 422.8 | 461.5 | 12.1 | 7346.6** | 749.5 | 639.4** | 5.7** | 2.8* |
| Location*Progeny | 63 | 352.8 | 398.4 | 452.3 | 11.3 | 3823.3 | 494.5 | 294.9 | 3.8 | 1.9 |
| Error | 210 | 316.3 | 350.6 | 381.9 | 8.9 | 3804.4 | 568.1 | 322.6 | 3.1 | 1.8 |
| Total | 383 | | | | | | | | | |

*, ** Significant at 0.05 and 0.01 probability levels, respectively

Table 4 - Means, estimates of genetic variance ($\sigma_G^2$), phenotypic ($\sigma_P^2$), genotype by environment interaction ($\sigma_{GE}^2$), experimental error ($\sigma_E^2$), heritability ($h^2$), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), gains from selection (Gs) and selection response (Rs) among 100 $S_2$ maize progenies grown in two high – Nitrogen environments in NIFOR, near Benin City and Ozoro, Delta State.

| Character | Mean | $\sigma_E^2$ | $\sigma_{GE}^2$ | $\sigma_G^2$ | $\sigma_P^2$ | $h^2$ | GCV | PCV | Gs | Rs |
|---|---|---|---|---|---|---|---|---|---|---|
| Days to 50% Pollen Shedding | 65.5 | 73.7 | 12.3 | 3.1 | 21.5 | 14.3 | 2.7 | 7.1 | 0.9 | 1.4 |
| Days to 50% Silking | 67.5 | 79.1 | 14.9 | 2.6 | 23.2 | 11.1 | 2.4 | 7.1 | 0.8 | 1.1 |
| Anthesis Silking Interval (ASI) | 2.0 | 4.0 | 0.7 | 0.3 | 1.3 | 22.1 | 27.5 | 58.6 | 0.4 | 18.1 |
| Days to 50% Tasselling | 62.3 | 66.2 | 13.2 | 1.1 | 18.8 | 6.1 | 1.7 | 7.0 | 0.4 | 0.6 |
| Leaf Area ($cm^2$) | 356.3 | 7772.4 | 652.5 | 2195.9 | 3817.6 | 57.5 | 13.2 | 17.3 | 49.8 | 14.0 |
| Plant Height (cm) | 109.6 | 1254.5 | 374.5 | 58.3 | 454.6 | 12.8 | 7.0 | 19.5 | 3.8 | 3.5 |
| Leaf Senescence | 11.2 | 1429.9 | -36.6 | -9.8 | 210.2 | -4.7 | | 129.6 | -0.9 | -8.5 |
| Ear Height (cm) | 51.6 | 5216.6 | -53.2 | -60.7 | 782.2 | -7.8 | | 54.2 | -3.0 | -5.9 |
| Grain Yield (t $ha^{-1}$) | 2.25 | 985542.0 | 168431.0 | 364633.0 | 613106.0 | 59.5 | 26.9 | 34.9 | 0.7 | 29.0 |

trary, estimates of genetic component of variance for morphological characteristics and grain yield under high N were greater than low N excepted for leaf senescence and ear height.

Estimates of phenotypic component of variance ($\sigma_p^2$) for flowering characteristics were greater under low N than under high N. However, estimates of phenotypic component of variance among morphological characters and grain yield were greater under high N than under low N.

The heritability estimates for flowering characters were greater under high N than under low N. Also, heritability estimates for grain yield under high N was 59.5%, but it was 33.0% under low N. The estimates of heritability for leaf area and plant height under high N were 57.5% and 12.8%, respectively. On the contrary the estimates of heritability for leaf area and plant height under low nitrogen were 47.7% and 33.6%, respectively.

Among the flowering characters estimates of genotypic coefficient of variation (GCV) were greater under high N than under low N, except for days to 50% flowering. Also estimate of GCV for grain yield under high N was greater compared to low N. However, estimates of GCV for leaf area, plant height, leaf senescence and ear height were greater under low nitrogen than high nitrogen.

Estimate of phenotypic coefficient of variation (PCV) for ASI was greater under high N. However, the estimates of PCV for other flowering characters were lower under high N than low N.

The estimates of gains from selection (Gs) and selection response (Rs) for grain yield under high N amounted to 652.0 and 29.0, respectively. In low N environment, Gs and Rs for grain yield amounted to 0.3 and 0.3, respectively. Also, under high N, there were appreciable Gs and Rs for ASI and leaf area compared to low N.

## Discussion

The superior performance and significant differences in most of the observed secondary agronomic characters and grain yield among the 100 high N $S_2$ progenies can be attributed to the optimum growth conditions provided by high N environments. The low performance and significant differences in grain yield and a few secondary agronomic characters among the 64 low N $S_2$ progenies was traceable to nitrogen stress in low N environments. Nitrogen stress resulted in reduction of growth (height) and yield of low N S2 progenies by 52.3% and 94.5%, respectively. The intensity of maize grain yield reduction was greater than the results of previous studies (Wolfe et al, 1988; Logrono and Lothrop, 1997; Banziger et al, 1997 Meseka et al, 2006).

Nitrogen stress intensities which result in more than 43% relative yield reduction may not be representative of farmers' field in temperate areas (Brun and Dudley, 1989; Carlone and Russel, 1987; Duvick, 1984; Moll et al, 1987), but may occur frequently in farmers' fields in the tropics (McCown et al, 1992; van Reuler and Prins, 1993).

The significant mean squares for most of the observed secondary agronomic characters and grain yield among the 100 high nitrogen $S_2$ progenies ($P<0.01$) indicated significant genetic variation. Among the 64 low N $S_2$ progenies grown under low N, significant mean squares in a few secondary agronomic characters such as leaf area, ear height and leaf senescence ($P<0.01$) and grain yield ($P<0.05$) also indicated significant genetic variation. These results are in agreement with data reported by others (Ceccarelli et al, 1987, 1992; Lafitte and Edmeades, 1994; Santos et al, 1998).

It can be inferred from the results that there was greater genetic variability in both secondary agronomic characters and grain yield among the 100 high N $S_2$ progenies (evaluated in high N environments) than the 64 low N $S_2$ progenies (evaluated in low N environments). Genetic variability is an indispensable pre-requisite for breeding progress. The indication is that genetic variation in both secondary agronomic characters and grain yield is dependent on the crop environment (Santos et al, 1998).

The greater genetic variability in agronomic characters among high N $S_2$ progenies under high N environments was also followed by significant high N progenies-by-environment interactions for most of the observed characters. The implication of this is that the superiority they have in optimum environment may not be expressed in sub-optimal environments (Ceccarelli, 1994).

Although lesser genetic differences was observed among low N $S_2$ progenies in low nitrogen environments, the results have demonstrated that if selection is directed at the development of genotypes to be utilized in stressed environments, breeding should be developed in soils with deficiencies to satisfy this requirement (Clark, 1982), since in addition to the many factors that influence plant adaptation to stress conditions (Epstein, 1976), there is also an interaction between nutrient availability and deficiency and climatic factors (Dudal, 1976).

Low N environment resulted in lower broadsense heritability than high N in most of the observed agronomic characters except plant height, leaf senescence and ear height. The lower heritability estimates in low N environment was due more to decreased genotypic variances than increased error variances. Lower genotypic variance and lower heritability for grain yield under stressed conditions have been reported in many other studies (Atlin and Frey, 1990; Banziger et al, 1997; Frey, 1964; Quisenberry et al, 1980; Ud-Din et al, 1992; Hefny, 2007). Several investigations additionally found that error variances decreased under stressed conditions (Atlin and Frey, 1989, 1990; Pederson and Rathjen, 1981; Ud-Din et al, 1992) leading in a few instances to increased heritability estimates under stress conditions (Atlin and Frey, 1989; Pederson and Rathjen, 1981). In this present study error variances differed between low and high N, they tended to increase among flowering characters and decrease among morphological characters and grain yield. Banziger et al (1997) reported that error variances did differ significantly between low and high N, but they tended to decrease with increasing relative yield reduction of low N experiments.

Estimates of genotype x environment variance for some morphological characters and grain yield were greater in high N than low N. The high genotype x environment variances for grain yield and some morphological characters in high N environment emphasize the need for multi environment testing to identify nitrogen - use efficient cultivars with broad adaptation to different levels of N availability. Diversity in soil type and climatic conditions resulted in large productivity difference at the both locations and may have contributed to the high genotype x environmental variances (Presterl et al, 2003). Banziger et al (1997) reported that if potential genotype x environment variances consistently differ between low and high N, this could affect the relative magnitude of genetic variances and broadsense heritabilities at low vs high N, and consequently could affect conclusions regarding selection efficiency. Genotype x environment interactions have usually been examined for stress and non - stress conditions without discriminating between genotype x environment interactions resulting from the stress of interest and genotype x environment interaction resulting from other growth factors (Atlin and Frey, 1990; Ud-Din et al, 1992).

The results obtained from this study have unambiguously demonstrated that the magnitude of genetic variances, heritability and gains from selection are dependent on the nature of the crop environment. This means that the more a crop environment attains optimal growth conditions especially with respect to nutrient level, the greater are the chances of attaining maximum genetic variability and ultimate chances of genetic gains from selection (Emede and Alika, 2005). Rosielle and Hamblin (1981) and Gamma et al (2001) have similarly observed the same relationship between stress environments and genetic variability for maize grain yield.

Inspite of lower heritability under stress conditions, many studies have predicted selection under stress conditions to be more efficient than selection under non-stress conditions for targeting stress environment (Atlin and Frey, 1990; Ceccarelli et al, 1992;

Table 5 - Means, estimates of genetic variance ($\sigma_G^2$), phenotypic ($\sigma_P^2$), genotype by environment interaction ($\sigma_{GE}^2$), experimental error ($\sigma_E^2$), heritabilities($h^2$), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), gains from selection (Gs) and selection response (Rs) among 64 $S_2$ maize progenies grown in two low – Nitrogen environments in NIFOR, near Benin City and Ozoro, Delta State.

| Character | Mean | $\sigma_E^2$ | $\sigma_{GE}^2$ | $\sigma_G^2$ | $\sigma^2$ | $h^2$ | GCV | PCV | Gs | Rs |
|---|---|---|---|---|---|---|---|---|---|---|
| Days to 50% Pollen Shedding | 63.9 | 350.6 | 15.9 | 4.1 | 70.5 | 5.8 | 3.2 | 13.1 | 0.7 | 1.1 |
| Days to 50% Silking | 67.5 | 381.9 | 23.4 | 1.5 | 76.9 | 2.0 | 1.8 | 13.0 | 0.2 | 0.4 |
| Anthesis Silking Interval (ASI) | 3.6 | 8.9 | 0.8 | 0.1 | 2.0 | 7.2 | 10.5 | 39.4 | 0.1 | 4.0 |
| Days to 50% Tasselling | 61.1 | 316.3 | 12.2 | 5.2 | 53.6 | -9.8 | | 12.0 | -1.0 | -1.6 |
| Leaf Area(cm2) | 128.3 | 3804.4 | 6.3 | 580.4 | 1217.6 | 47.7 | 18.8 | 27.2 | 23.3 | 18.1 |
| Plant Height(cm) | 51.7 | 568.1 | -24.5 | 41.7 | 124.1 | 33.6 | 12.5 | 21.5 | 5.2 | 10.1 |
| Leaf Senescence | 2.3 | 3.1 | 0.2 | 0.3 | 1.0 | 34.1 | 25.2 | 43.1 | 0.5 | 20.6 |
| Ear Height(cm) | 44.7 | 322.6 | -9.2 | 57.4 | 106.6 | 53.9 | 17.0 | 23.1 | 7.8 | 17.4 |
| Grain Yield(t/ha) | 0.12 | 1.8 | 0.0 | 0.2 | 0.5 | 33.0 | 0.3 | 0.6 | 0.0003 | 0.3 |

Pederson and Rathjen, 1981; Ud-Din et al, 1992). The study by Banziger et al, (1997) showed that the superiority of selection under either stress or non–stress conditions may depend on the stress intensity in the target environment: As genetic correlations between grain yields under low and high N decreased with increasing relative yield reduction under low N, indirect selection under high N became less efficient.

*Conclusion*

This present study has further demonstrated that $S_2$ progeny selection enhances sustainability of genetic variability for grain yield even under nutrient stress environment. Genetic variability for characters such as tasseling, pollen shed and silking dates were adversely affected by soil nutrient stress. The results indicated that variances, heritability estimates and predicted gains from selection were substantially lower among low N $S_2$ progenies in nutrient stress environment than those in optimum environment for all traits. It means therefore that selections will be less effective in low N stress environments. However, selection gains can be increased if low N selection environments are included in maize breeding programmes targeting such areas. In further studies, top ten $S_2$ progenies selected from each of the high and low N progenies would be combined to form a new population for subsequent cycles of selection in high and low N environments.

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